Endangered Species Habitat Restoration Issues in the Middle Rio Grande

Executive Summary

Prepared for:

MIDDLE RIO GRANDE
ENDANGERED SPECIES ACT COLLABORATIVE PROGRAM
HABITAT RESTORATION SUBCOMMITTEE

Funding Provided by the New Mexico Interstate Stream Commission

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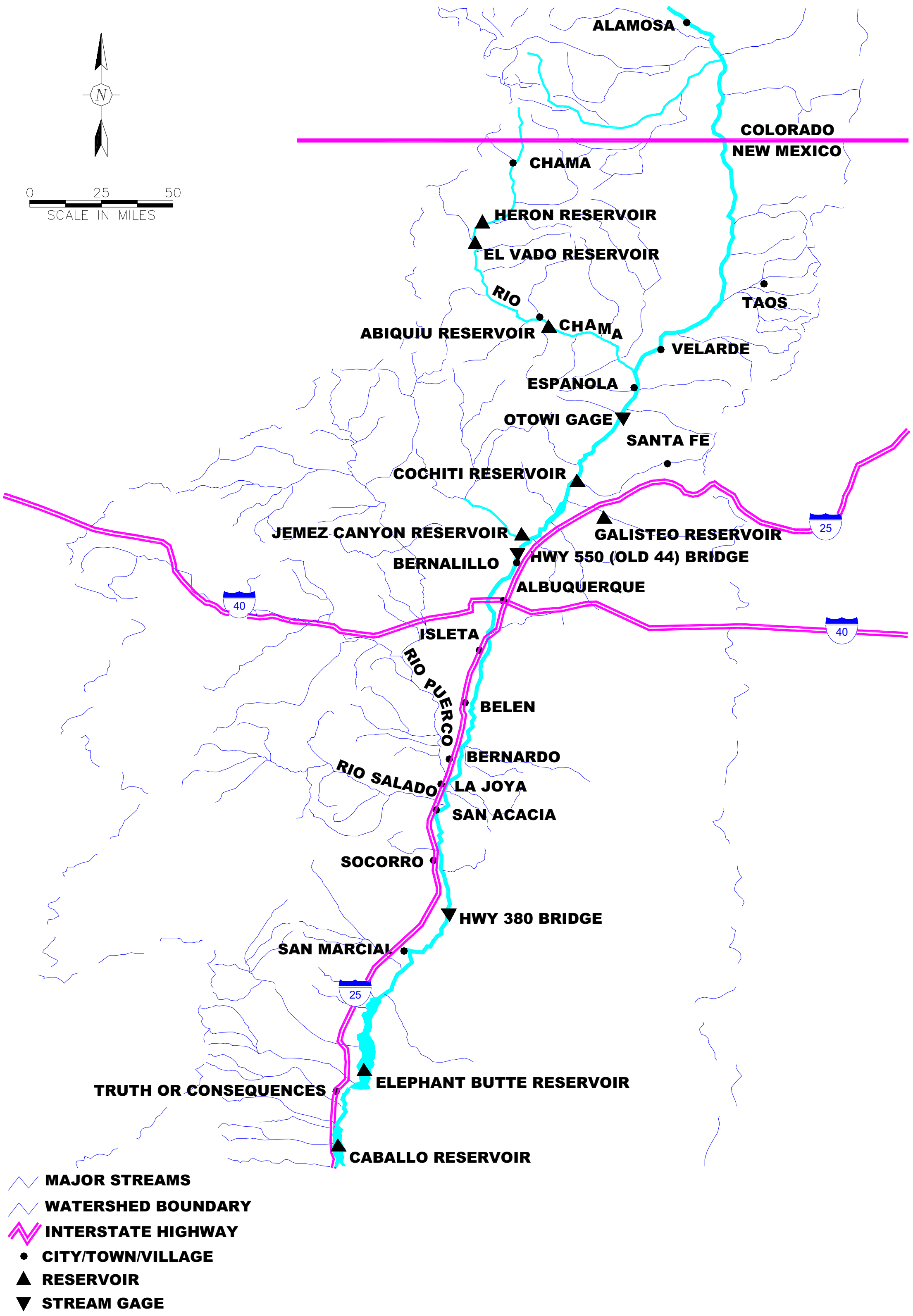
Figure 1. Middle Rio Grande Watershed



INTRODUCTION

The Middle Rio Grande Endangered Species Act Collaborative Program (Program) was established to provide a framework for coordinated actions to enhance habitat, increase populations, and contribute to the recovery of the Rio Grande silvery minnow (silvery minnow; *Hybognathus amarus*) and southwestern willow flycatcher (flycatcher; *Empidonax traillii extimus*). The Program seeks to achieve these goals within the confines of applicable State and Federal laws, while respecting existing water rights and Rio Grande Compact requirements.

The Habitat Restoration Subcommittee (Subcommittee) was established to develop a comprehensive habitat restoration plan for the Program. This document focuses on the river and associated riparian zone from Velarde to the headwaters of Elephant Butte Reservoir (Figure 1). The Program defines the Middle Rio Grande (MRG) geographically to include the Rio Grande from the New Mexico-Colorado border and the Rio Chama headwaters to the elevation of the spillway of the Elephant Butte Reservoir (4,450 feet mean sea level).

Because the Subcommittee is composed of members with diverse technical backgrounds and includes non-professional participants from the public, establishing a common understanding of components of the system was deemed an important precursor to the development of a comprehensive habitat restoration plan. Consequently, the Subcommittee agreed to first develop a series of white papers to improve the understanding of the physical and biological processes that are important to the recovery of silvery minnow and flycatcher populations and the management of water resources in the MRG.

The purpose for developing these white papers, compiled here as a single document, was to promote discussion and the free exchange of ideas within the Subcommittee. Tetra Tech EM Inc. (Tetra Tech) was retained by the New Mexico Interstate Stream Commission to develop these white papers to support its commitment to the Program. The original papers were reviewed by individuals participating in the Subcommittee and then revised by Tetra Tech to better reflect the opinions of the reviewers.

Overall, the intent in developing this document was to achieve a technically defensible consensus among stakeholders concerning the fundamental physical, biological, and ecological attributes pertinent to restoration in the MRG. This document was designed to emphasize critical issues related to habitat restoration, rather than provide lengthy reviews of all aspects of a particular subject.

This document is structured in chapters dealing with aspects important to restoration of silvery minnow and flycatcher habitat in the MRG. Individual white papers were developed for the Rio Grande silvery minnow, southwestern willow flycatcher, net depletions of water, hydrology, geomorphology, existing habitat, and estimated future habitat conditions. They are combined herein to provide the reader with an overview of the important issues associated with restoration in the MRG. The chapters are summarized below.

CHAPTER I
SILVERY MINNOW

The entire wild population of the silvery minnow is restricted to the MRG. Our understanding of silvery minnow habitat comes from field observations under contemporary conditions and comparisons to related species in other river systems. Research on the silvery minnow is ongoing, and many aspects of the biology and reproductive ecology are still poorly understood. Low population densities complicate achieving a reliable census. The principal immediate threat to the species is associated with the concentration of the population in the lower reaches of the Rio Grande above Elephant Butte Reservoir, which are prone to transient drying. Threats associated with water quality, food resources, and predation are not fully understood. Currently, aquaria and naturalized refugia have been constructed and provide stock for release into the Rio Grande.

CHAPTER II
FLYCATCHER

Roughly ten percent of the total flycatcher population breeding in the Southwest breed along the Rio Grande. A migratory species, the flycatcher winters in Mexico and Central America and travels to the southwestern United States to breed. The distribution of the flycatcher has not diminished, but the amount and quality of breeding habitat has declined. The flycatcher has been more extensively studied than the minnow, and the habitat requirements are fairly well known.

CHAPTER III
DEPLETIONS

Because restoration activities can result in gains or losses of water and have the potential to change the river hydrograph, characterization of the water requirements of restoration activities is important to maximize the benefits to the listed species while still providing water to valid water rights holders in the MRG and maintaining New Mexico's obligation relative to the Rio Grande Compact. Chapter III defines depletions in the context of the Rio Grande Compact and discusses some of the associated technical issues.

CHAPTER IV
HYDROLOGY

Water in the MRG basin is fully appropriated, and a large portion of the river flow must be delivered to Texas under the Rio Grande Compact. Thus, changes in the amount of water needed for restoration or to achieve mandated target flows may have important societal, economic, and ecological consequences. Ultimately, if additional water is needed for endangered species, an existing water use must be suspended. The intent of Chapter IV is to provide an overview of the hydrology of the MRG with an emphasis on contemporary conditions, including a summary of the institutional constraints associated with the water management facilities.

The hydrology of the Rio Grande has been modified by the human occupation in the basin since at least the 16th century. Significant changes in the hydrology resulted from agricultural developments in the late 1800s and flood control and water management systems implemented throughout the 20th century. Episodic floods and periods of low flow associated with droughts characterize the native hydrology of the Rio Grande. The primary effects of the 20th century water management practices were to moderate extreme flows and promote a more consistent flow regime throughout the year.

CHAPTER V
GEOMORPHOLOGY

Changes in the Rio Grande's hydrologic regime and physical changes to the river channel imposed by flood control, channelization, and water operations are manifest in the current geomorphology of the river in the MRG. The nature of the channel and floodplain and the course of the river have been altered, resulting in less than optimal conditions for the silvery minnow at certain times of the year. Understanding the rate and direction of geomorphic change and the implications for habitat will require additional research.

CHAPTER VI
EXISTING HABITAT CONDITIONS

The intent of this chapter is to examine current knowledge concerning existing habitat conditions for the silvery minnow and flycatcher to facilitate long-term habitat restoration planning. A detailed and comprehensive characterization of habitat resources in the MRG is lacking for both the silvery minnow and flycatcher. Useful working relationships regarding habitat for these species exist, even though specific habitat requirements for all life stages of the silvery minnow and flycatcher are incompletely understood and remain topics of research. Overall, the habitat requirements of the flycatcher are better defined than those of the silvery minnow. In general, channel conditions, including bed substrate and flow velocities, are favorable for the minnow in the lower reaches, although water supply is tenuous at some times. The upper reaches tend to have less favorable channel conditions for the minnow, but a more reliable water supply. Notably, egg retention and rearing habitats are generally lacking in the upper reaches.

CHAPTER VII
ESTIMATED FUTURE CONDITIONS

The intent of Chapter VII is to discuss future conditions in the MRG, with an emphasis on silvery minnow and flycatcher habitats. In the absence of intervention, habitat conditions for the silvery minnow and flycatcher in the MRG are not expected to improve. Locally, the silvery minnow is generally considered to be at greater risk than the flycatcher, because its population is restricted entirely to the Rio Grande.

In the very near term, the most pressing issue for the silvery minnow is associated with water supply, especially considering the concentration of the population in the lower reaches of the MRG. Continuation of the drought conditions that characterized 2001 will necessitate pumping water from the Low Flow Conveyance Channel to the river in the San Acacia reach and rescue operations. The aquaria program will continue to be an important safeguard for the silvery minnow until the population is increased and habitat conditions are stabilized throughout the MRG.

From a longer-term perspective, the trends in geomorphology are not considered favorable with regard to promoting silvery minnow habitat in the upper reaches, and episodic droughts will continue to stress the water supply. Thus, efforts that promote habitat improvement in the upper reaches and mechanisms for providing the optimal amount and seasonal distribution of water for the minnow and water rights holders are critical to stabilizing the silvery minnow population.

Flycatcher habitat is expected to be adversely impacted by increases in urban development, catastrophic fires, and changes in plant communities associated with the progressive invasion of exotic trees. The successful establishment of flycatcher breeding territories in saltcedar and Russian olive confounds the interpretation of the long-term effects of fire and shifts in plant community composition on flycatcher habitat.

ACKNOWLEDGEMENTS

The Subcommittee attempted to substantiate the accuracy of the information contained in the white papers; however, the views expressed are the those of the authors (Tetra Tech) and do not necessarily reflect those of the Subcommittee or its individual participants. Many Subcommittee participants and reviewers are employees of New Mexico State and Federal agencies. However, the contents of this publication do not necessarily reflect the views and policies of the State of New Mexico or the United States Government.

Major reviewers or contributors to this document are listed below. Questions and comments can be directed to Dr. Lewis Munk at Tetra Tech.

City of Albuquerque (COA)

Middle Rio Grande Conservancy District (MRGCD)

New Mexico Department of Game and Fish (NMGF)

New Mexico Interstate Stream Commission (NMISC)

Rio Grande Restoration

U.S. Bureau of Reclamation (BOR)

U.S. Army Corps of Engineers (COE)

U.S. Fish and Wildlife Service (FWS)

I. RIO GRANDE SILVERY MINNOW

The silvery minnow is listed as endangered by the FWS and the states of New Mexico and Texas (FWS, 1994; NMGF, 1996; Texas Parks and Wildlife (TPW), 2003). Historically, it was one of the most common fish in much of the Rio Grande and Rio Chama. The population ranged from the Gulf of Mexico to Espanola on the main stem and up to Abiquiu on the Rio Chama (Bestgen and Platania, 1991). The silvery minnow also occurred in the Pecos River from Santa Rosa south to the confluence with the Rio Grande. Of the five native cyprinids endemic to this basin, the silvery minnow is the only remaining member of this guild that has not been extirpated from the Rio Grande or become extinct (Propst, 1999).


U.S. Fish and Wildlife Service

Rio Grande Silvery Minnow

Currently, silvery minnows inhabit about 10 percent of their historic range and occur only between Cochiti Dam and Elephant Butte Reservoir. About 95 percent of the fish are estimated to occur between the San Acacia Diversion Dam and Elephant Butte Reservoir, although low population densities complicate achieving a reliable census (Dudley and Platania, 1999; FWS, 2003a, 2003b). Because portions of the San Acacia reach are susceptible to desiccation, recovery efforts are complicated by the current distribution of the silvery minnow.

LIFE HISTORY

The silvery minnow is a pelagic (open water) broadcast spawner that releases nonadhesive, semibuoyant eggs into the water column where they are fertilized. A single female can broadcast over 3,000 eggs during a single spawning event and multiple spawning events can occur (Platania, 1995; Platania and Altenbach, 1998). Water currents maintain the eggs in suspension and, depending on water temperature, the larvae hatch within 1 to 2 days after fertilization. The larvae develop sufficient swimming ability to escape the current 2 to 3 days after hatching. During this combined 3- to 5-day period, free-floating eggs and larva drift with the currents (Platania and Altenbach, 1998).

In the wild, silvery minnow generally do not survive many months beyond their first reproductive period near 1 year of age. Typically, fish older than 1 year make up less than 10 percent of the spawning population of the silvery minnow (FWS, 2003a, 2003b). In captivity, however, a majority of the silvery minnow stock can live beyond 1 year. The dominant cause of mortality in the wild after 1 year has not been documented but may be related to inadequate food supplies, predation, and disease.

GENERAL HABITAT

Our understanding of silvery minnow habitat comes primarily from field observations under contemporary conditions and comparisons to related species in other river systems. Interpretations of the habitat requirements of the silvery minnow have changed over time to reflect the conditions that prevailed during the particular study. Thus, optimum habitat conditions for the minnow are equivocal and based on a limited number of observations in a degraded river system. Koster (1957) described the habitat of the silvery minnow as "pools and backwaters of the main rivers and creeks" where they schooled and fed "largely on bottom mud and algae." Sublette et al. (1990) reported that while the silvery minnow tolerates "a wide variety of habitats, it prefers large streams with slow to moderate current over a mud, sand or gravel bottom." Bestgen and Platania (1991) observed that most silvery minnows "were captured in low-velocity habitats that had sand substrate."

Dudley and Platania (1997) reported that habitats occupied by the silvery minnow changed with age. Young fish (up to 20 mm) were most commonly found in shallow (15 cm deep) backwater pools with silt bottoms, whereas mature fish (40 to 70 mm) were more prevalent in deeper (40 to 50 cm) pools and particularly in areas with debris and increasing proportions of sand and gravel. In general, silvery minnows use deeper waters during the winter compared to the summer. Winter habitat was reported to be moderately-deep, slow-flowing water along the shore and often associated with debris piles (Dudley and Platania 1996, 1997). Watts et al. (2002) reported that shoreline habitats with debris were used more commonly than open-water habitats lacking debris.

REPRODUCTIVE ECOLOGY

Because reproduction is vital to perpetuating populations of fish in streams that are susceptible to transient desiccation, understanding the timing and duration of spawning, egg dispersal, and migration is important when developing restoration strategies. The conditions that trigger spawning in the silvery minnow are not completely known; however, peak spawning is correlated with increased flow in the spring (Platania and Dudley, 2002a, 2002b). Silvery minnows spawn from April through at least June, with the peak egg production occurring in mid to late May, coinciding with spring runoff (Platania and Dudley, 2002a, 2002b). Peak egg production occurs over about 3 days, with sporadic or low-level spawns occurring over the next 4 to 6 weeks (Platania and Dudley, 2002a, 2002b).

Following the peak spawn, pulsed increases in flows apparently do not trigger significant egg production, and minor spawns have been observed with no apparent increase in flow (Platania and Dudley, 2002a, 200b). The spring spawn appears correlated with peaking flows but not necessarily with maximum flow volumes. Temperature, sediment (turbid water), and photoperiod have been suggested as other possible triggering mechanisms, although their role in initiating spawning has not been experimentally demonstrated.

A protracted spawning period extending into the summer monsoon period (July and August) is speculated to have occurred under historically natural conditions (J. Brooks, FWS). The present-day contracted spawning period is attributed to premature mortality associated with low-flow conditions following spring runoff (J. Brooks, FWS) or inadequate food sources (M. Porter, BOR).

Broadcast spawning enhances the reproductive success of some fish species by reducing egg burial and suffocation in rivers with shifting sand beds (Araujo-Lima and Oliveira, 1999). However, this reproductive strategy, which once provided the silvery minnow with a competitive advantage in the Rio Grande, may now be detrimental under the prevailing conditions in the MRG. Historical river maintenance and channel straightening activities have reduced the amount of low-velocity flow environments available during spawning periods and the potential for egg and larval retention in the upper reaches. Platania and Altenbach (1998) estimated that eggs and larvae entrained in the mid-channel flows could potentially be transported 100 to 200 miles downstream in the 3 to 5 days required to develop swimming abilities after fertilization of the eggs.

The actual egg and larval transport distances are unknown, but the current distribution of the minnow suggests that the existing conditions in the river promote downstream displacement of the population. Because most individuals in the wild only live about 1 year, significant annual upstream movement of young-of-year would be required to repopulate the natal areas if the majority of the population was displaced downstream. While recent studies have shown that silvery minnows have potentially strong swimming abilities (Bestgen et al., 2003), evidence of long-distance migration by this fish is lacking. One tagged individual swam 15 to 20 miles upstream to the base of the San Acacia Dam over a 6-month period (M. Porter, BOR). While diversion structures can block upstream movement by fish, the cumulative effects of diversion structures are difficult to predict without understanding the silvery minnow's upstream swimming capabilities. Of note, silvery minnows have coexisted with the MRG irrigation structures for over seven decades.

The dispersal and fate of eggs is important to silvery minnow survival, especially since the population is concentrated in the river's lower reaches, which are susceptible to transient desiccation. Consequently, the development of habitat restoration options for the silvery minnow should consider efforts that promote the retention of eggs and young in the upstream reaches of the MRG that have a more reliable water supply.

FOOD HABITS

The specific food habits of the silvery minnow are poorly defined. Qualitatively, the silvery minnow diet is considered comparable to closely related species that primarily feed on diatoms, algae, larval insect skins, and plant material contained in the ooze of bottom sediments (Sublette, et al., 1990; Hlohowskyj et al., 1989). Larval and adult silvery minnows apparently have similar diets, although algae are considered somewhat more important than other foods in the early life stages. The adequacy of food resources for the silvery minnow in the MRG has not been documented.

ENVIRONMENTAL STRESSES

Declines in the silvery minnow population are attributed to "dewatering, channelization, and regulation of river flow to provide water for irrigation; diminished water quality caused by municipal, industrial, and agricultural discharges; and competition or predation by non-native species" (FWS, 1994). Reservoirs and diversions are a concern because they can disrupt longitudinal continuity, affect channel morphology, and alter natural cycles of flow, water temperature, and sediment supply. Changes in channel configuration associated with channel straightening, jetty jacks, and grade controls may affect the silvery minnow by altering nutrient cycling, water supply, and sediment bed substrate relations. Competition and hybridization with non-native fish (i.e., plains minnow, *Hybognathus placitus*) was suggested as a major contributor to the extirpation of the silvery minnow from the Pecos River (Bestgen and Platania, 1991). However, recent assessments suggest that interactions with the plains minnow do not significantly impact the silvery minnow (C. Hoagstrom and J. Brooks, FWS). Northern pike, walleye, white bass, trout, and smallmouth bass introduced into reservoirs and drains may prey on the silvery minnow.

Elevated water temperatures and low dissolved oxygen concentrations in pools associated with the drying river contribute to the mortality of silvery minnows in the Rio Grande during periods of channel drying (FWS, 2003a, 2003b). Other than these conditions, however conclusive evidence that degraded water quality impacts the silvery minnow, or other aquatic populations, in the MRG is lacking. In 2001, the New Mexico Environment Department (NMED, 2001) concluded that water quality in the MRG was not impairing aquatic life.

Parsons Engineering (2000) evaluated water quality data from runoff samples collected from six locations in the City of Albuquerque from May to October 1992 and concluded that no acute toxicity hazards existed for aquatic life.

Buhl (2002) performed laboratory toxicity tests on silvery minnows using various concentrations of aluminum, ammonia, arsenic, chlorine, copper, and nitrate. He concluded that, "these chemicals individually or combined as environmentally relevant concentrations do not pose an acute hazard to populations of Rio Grande silvery minnow..." Chronic toxicity effects on silvery minnow growth and reproduction and the indirect effects of water quality on primary production (food chain effects) have not been investigated.

Mike Harvey

Algal accumulation on sand ripples

II. SOUTHWESTERN WILLOW FLYCATCHER

The flycatcher was listed as endangered due to "extensive loss of habitat, brood parasitism, and lack of adequate protective regulation" (FWS, 1995). New Mexico, Colorado, California, Texas, and Utah list the flycatcher as endangered, and it is on the draft list of Wildlife of Special Concern in Arizona. It is considered Critically Impaired in Nevada.

A migratory species, the flycatcher winters in Mexico and Central America and travels to the southwestern United States to breed. The breeding range of the flycatcher is centered in New Mexico, Arizona, and southern California, although it extends into the fringes of the adjoining states (Nevada, Utah, Colorado, and Texas) and northern Mexico. The Rio Grande valley is generally considered to be the eastern extent of flycatcher breeding, although some individuals nest along the Canadian River and perhaps the Pecos River in New Mexico.

The distribution of the flycatcher has apparently not diminished, but the amount and quality of breeding habitat has declined. The Rio Grande, from the headwaters to the Pecos River confluence, supports about 90 territories or roughly 10 percent of the range-wide total identified for the flycatcher in 1999 (FWS, 2002). Thus, the Rio Grande ecosystem is important to maintaining the viability of the population.

LIFE HISTORY

The flycatcher is a small, neotropical, passerine (perching) bird about 15 cm (5.8 inches) long. It is one of 11 *Empidonax* that breed in North America (Sogge and Marshall, 2000). This subspecies is distinguished based on morphology, song type, habitat use, structure and placement of nests, ecological separation, and genetic distinctness.

Flycatchers begin to arrive at New Mexico breeding ranges in early May. Males usually arrive a week or so ahead of females and yearlings and establish territories. They begin the southern migration in July through August. Flycatchers tend to return to the same general breeding area year after year, but not necessarily to the same nesting site or territory. In some instances, individuals migrate to new breeding areas in entirely different watersheds.

U.S. Forest Service

Southwestern Willow Flycatcher

Common predators of the flycatcher include great-tailed grackles (*Quiscalus mexicanus*), magpies (*Pica pica*), common ravens (*Corvus corax*), snakes, and especially brown-headed cowbirds (*Molothrus ater*). Grackles and ravens prey directly on flycatcher eggs and young. Cowbirds are brood parasites that destroy flycatcher eggs and then lay their eggs in host nests to be raised by flycatchers. The grackle, raven, and cowbird are natural predators whose population may be favored by agricultural and urban developments. The flycatcher life span is generally 1 to 3 years, with some individuals living 4 to 7 years (Langridge and Sogge, 1997; Paxton et al., 1997; Netter et al., 1998).

GENERAL HABITAT

The flycatcher is a riparian obligate bird. Breeding habitat is typically composed of a dense, homogenous understory of trees or shrubs with interlocking canopies (3 to 4 m above ground) interspersed with open areas and taller trees.

Flycatchers prefer stands or patches that are 0.6 hectares (1.5 acres) or larger (Sogge et al., 1997). Most sites are near standing or slow moving waters or areas with saturated soils. Historically, flycatcher habitat along the Rio Grande consisted primarily of thickets of willow (*Salix* spp.) and seepwillow (*Baccharis* spp.), sometimes with an overstory of scattered cottonwood (*Populus* spp.) (Grinnell and Miller, 1944; Phillips, 1948; Unitt, 1987).

Mark Sogge

Suitable flycatcher breeding habitat in the MRG

REPRODUCTIVE ECOLOGY

Currently, breeding habitat used by flycatchers along the Rio Grande consists of plant communities consisting of both native and non-native species. In addition to using willows, flycatchers in the MRG will build nests in Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*) in mixed native and non-native stands. The largest concentration of breeding territories along the MRG occurs in stands of Gooding's willows (*Salix goodingii*) in the San Marcial reach (G. Dello Russo, FWS). Nesting success rates are comparable between flycatchers using saltcedar-dominated habitats and those nesting in native vegetation (Sferra et al., 2000).

Several studies have found areas containing apparently highly suitable nesting habitat that lacked nests even though non-nesting individuals occupied the site (FWS, 2002; Moore and Ahlers, 2003). Thus, either surplus habitat exists in the MRG or there are additional factors that affect nesting that have not been identified. The potential effects on recruitment of habitat conditions along migration routes and in the winter range are problematic (FWS, 2003a).

Flycatcher breeding territories are typically 0.2 to 0.5 hectares (0.5 to 1.2 acres) in size, although they can be larger, depending on habitat quality and population density. Flycatchers are rarely found in patches that are narrower than about 10 m (33 feet) (Sogge and Tibbitts 1994; Sogge and Marshall 2000). The criteria females use to select a territory are unknown but may be related to habitat or mate quality.

Flycatchers build nests and lay eggs in late May and early June, with young fledged by early July; however, reproduction is locally affected by altitude, latitude, and renesting attempts. Female flycatchers construct nests of shredded bark, cattail tufts, grass, and feathers over a 4 to 7 day period. They generally lay one egg per day until there are 3 to 4 eggs in the nest (Gorski, 1969). If multiple breeding attempts are made in one season (i.e., renesting in response to failure of the first attempt due to parasitism or predation), then the clutch size is typically smaller (Holcomb, 1974; McCabe, 1991; Whitfield and Strong, 1995).

The females, or rarely males, incubate the eggs for about 2 weeks. Nearly 2 additional weeks are required for the hatchlings to mature and fledge from the nest, after which the young remain in their parent's territory for about another 2 weeks. The male and female continue to feed them during this time. Little is known about fledgling activities after this period (FWS, 2003a).

FOOD HABITS

An aerial forager, the flycatcher typically catches insects on the wing but also gleans them from foliage and the ground. Flycatchers forage within and above the canopy, in openings between patches of dense vegetation, over open water, and throughout overstory and groundcover vegetation (Bent, 1960; McCabe, 1991). The diet of the flycatcher consists of small to medium-sized insects of primarily terrestrial origins, including flies, wasps, bees, flying ants, dragonflies, beetles, butterflies/moths, and caterpillars (Beal, 1912; McCabe, 1991; Drost et al., 2001; Delay et al., 2002). Occasionally, they consume small fruits, such as elderberries or blackberries, although this is not considered an important food source during breeding season (McCabe, 1991).


Mark Sogge

Unsuitable flycatcher breeding habitat in sparse understory in cottonwood gallery

ENVIRONMENTAL STRESSES

Losses of riparian communities and wetlands, as well as changes in plant community composition, have altered the flycatcher habitat along the MRG. Over the flycatcher's entire breeding range, habitat loss has occurred in association with urban and agricultural development, water diversion and channelization, impoundments, wildfires, livestock grazing, and recreational uses (Marshall and Stoleson, 2000). Pesticides and agricultural chemicals in irrigation return waters and sediment may adversely impact the flycatcher, but direct evidence for this hypothesis is lacking. Poorly managed grazing can reduce the amount and quality of breeding habitat. However, grazing in riparian areas within the MRG bosque is not considered a major threat to the flycatcher (Ahlers, 1999).

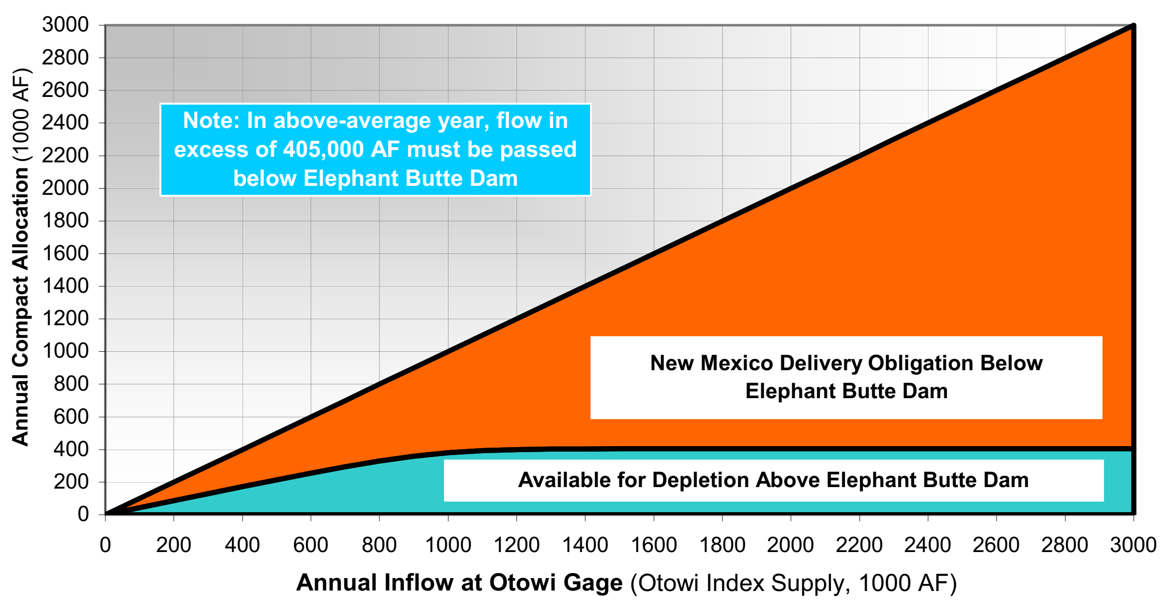
III. DEPLETIONS

River and riparian restoration projects are proposed for the MRG with the intent of protecting the silvery minnow and flycatcher habitats. Restoration practices that are broadly considered appropriate for the Rio Grande include manipulation of the flow regime, physical modifications of the channel/floodplain, and vegetation management. The water use requirements of the restoration activities vary depending on the nature, extent, and location of the project. Because restoration activities can result in gains or losses of water and have the potential to change the river hydrograph, characterizing the requirements of restoration activities is important in order to maximize the benefits to the listed species while still maintaining New Mexico's obligations relative to the Rio Grande Compact and water users throughout the MRG.

Water in the MRG basin is fully appropriated. Current estimates indicate that on average New Mexico has about a 50 percent chance of meeting the Rio Grande Compact delivery requirements in any year (S.S. Papadopulos & Associates [SSP&A], 2000). In the absence of exercising a water right based upon prior appropriation for beneficial use, the New Mexico Office of the State Engineer requires that any citizen or political subdivision of the state that pumps groundwater or diverts surface water to an extent that depletes native Rio Grande water must offset such depletions. In effect, any new use of water in the MRG requires that an existing use be retired.

The goal of the Rio Grande Compact was to equitably apportion the waters of the Rio Grande among Colorado, New Mexico, and Texas based on conditions that existed in 1929. Briefly, the Rio Grande Compact requires Colorado to deliver about one third of the flow of the Rio Grande originating in Colorado to New Mexico in average years, about one fourth of the flow in dry years, and about two thirds of the flow in wet years. Native Rio Grande flows at the Otowi gage define delivery requirements from New Mexico to Texas. About 60 percent of the native Rio Grande flow past the Otowi gage must be delivered to Texas in dry years and over 80 percent in wet years. New Mexico's total allocation of the flow at Otowi gage is capped at 405,000 AFY (Figure III-1). Tributary inflows below the Otowi gage can be used in the MRG. New Mexico's deliveries are measured as releases below Elephant Butte Reservoir, plus the net change in storage in the reservoir. San Juan Chama Project (SJCP) water flowing past the Otowi gage is excluded from Rio Grande Compact accounting and must be used consumptively within New Mexico.

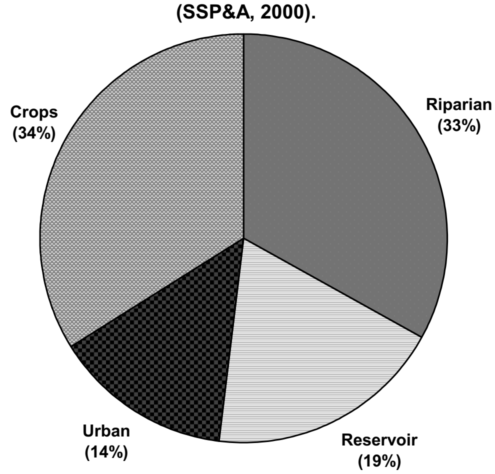
Figure III-1. Annual compact allocation.



DEPLETIONS

In the context of the Rio Grande Compact, depletions are defined as irrecoverable losses of water from agricultural and riparian vegetation, open water, bare channel sediments, and municipal and industrial use. Consumptive use refers to losses of water from a hydrologic system over a specified period through evaporation from soils and transpiration from plants, including water that is used to build plant tissue. In general, the magnitude of annual water loss from different surfaces occurs in the following order: pan evaporation > open water ≥ bare saturated soil > riparian vegetation > upland vegetation > dry soil. Because surface water and groundwater are connected in the MRG, seepage, transference losses, agricultural leaching, and groundwater recharge are not considered depletions. Similarly, groundwater pumping and increased transference efficiencies do not represent net gains in basin water supply.

Figure III-2. Mean total depletions in the MRG under present land use and groundwater development conditions (SSP&A, 2000).



Crop and riparian evapotranspiration (ET) account for the largest depletions in the MRG, followed by reservoir evaporation and urban depletions (Figure III-2).

RESERVOIR AND OPEN WATER DEPLETIONS

Open water evaporation represents a significant source of water loss in the MRG. The evaporative demand in this region is high, with average pan evaporation rates in the range of about 6 feet per year (1,800 mm/y^{-1}) at Los Lunas to almost 10 feet per year (3,000 mm/y^{-1}) at Elephant Butte Reservoir. Evaporation from Cochiti (5,000 to 20,000 AFY) and Elephant Butte (50,000 to 250,000 AFY) Reservoirs accounts for about 19 percent of the average annual water loss in the MRG (SSP&A, 2000). Reservoir evaporation is expected to range from about 60 to 85 percent of pan evaporation depending on the size of the water body and other factors. Smaller water bodies tend to have evaporation rates closer to pan evaporation rates.

Evaporation from the river, bare channel sediments, canals, and drains are also important components of the regional water balance. For instance, the active (bankfull) channel of the Rio Grande from Cochiti to the upper end of Elephant Butte Reservoir is estimated to occupy about 10,000 acres, excluding drains and canals. For comparison, the current (i.e., July 2002) pool surface of Elephant Butte Reservoir is about 10,000 acres, although it may range up to 36,500 acres at maximum capacity. Evaporation from wetted channels, canals, ditches, and drains is expected to occur at rates similar to those discussed above for open water bodies. Thus, during low storage years, channel and conveyance system depletions may rival losses from the reservoirs.

The rate of evaporation from saturated soils may equal open water evaporation rates during periods of low to moderate evaporative demand. Soil hydraulic properties and water table depth control the potential rate of evaporation from bare channel sediments. Thus, evaporation from exposed channel sediments may be significant even during low flow periods and should be considered in connection with restoration activities that involve channel widening.

Unlike in vegetated areas where dormancy and shading reduce evaporation rates during the nongrowing season, evaporation from open water and bare saturated soils occurs at the maximum climatically determined rate throughout the year. Water loss from the river channel, canals, and drains is currently included in the depletion estimates for the riparian zone (SSP&A, 2000).

RIPARIAN VEGETATION DEPLETIONS

Consumptive use associated with the riparian zone accounts for about a third of the average annual depletions in the MRG (SSP&A, 2000). Because the estimated riparian zone depletions include open water evaporation from the channel, the amount of water lost strictly to ET is unknown.

The potential for creating habitat for the listed species while reducing depletion through manipulation of vegetation is the driving force behind developing an understanding of riparian depletions.

The consumptive use of agricultural crops has been the subject of significant research, the results of which form the fundamental basis for understanding plant/soil water relations (Doorenbos et al., 1992; Hillel, 1998). In contrast, riparian vegetation ET is not well quantified from a comprehensive perspective, with past research focused mainly on saltcedar, rather than on the broad range of plants in riparian communities (Moore et al., 2000). Extrapolation of ET rates is problematic, because ET depends on complex interactions between plants, the soil, and the atmosphere (Hillel, 1998) and estimating ET rates is method dependent (World Meteorological Organization [WMO], 1971). Eddy covariance methods are thought to provide the most accurate estimates of ET; however, only a few studies have used this approach for riparian vegetation in the MRG.

Saltcedar stands are generally considered to use more water per unit area than native riparian stands (Gatewood et al., 1950; King and Bawazir, 2000). Sala et al. (1996) indicated that saltcedar ET rates were no greater than native phreatophytes on a leaf area basis, but saltcedar has the ability to form stands with higher total leaf areas than native phreatophytes resulting in higher overall water loss. Recent studies in the MRG using eddy covariance methods support this observation. King and Bawazir (2000) reported on annual ET rate of 4.4 ft (1,330 mm) for a dense saltcedar stand compared to 3.0 ft (904 mm) for a sparse cottonwood stand at Bosque Del Apache National Wildlife Refuge. Cleverly et al. (2002) reported that the annual ET for saltcedar stands measured in 1999 varied from about 4.2 ft (1,220 mm) at a flooded site to 2.4 ft (740 mm) at a non-flooded site. Coonrod and McDonnell (2001) indicated that annual ET measured in cottonwood stands in 2000 varied from about 2.4 ft (720 mm) at a flooded site to 3.0 ft (930 mm) at a non-flooded site. During the same measurement period, annual ET in saltcedar stands varied from 2.6 ft (780 mm) at a flooded site to 2.0 ft (600 mm) at a non-flooded site (Coonrod and McDonnell, 2001).

The variations in measured ET values for saltcedar and native stands indicate that local differences in stand characteristics, soils, ambient climate, depth to water table, and flooding complicate the extrapolation of ET data over time and space. Furthermore, these data suggest that conversion of saltcedar stands to native riparian communities may not always reduce depletions.

The BOR developed the ET Toolbox to estimate daily rainfall and water losses associated with crop and riparian ET and open water evaporation within specified river reaches (Brower et al., 2001). The ET Toolbox makes estimates of water loss for various land, vegetation, and water components on a 4-km grid. Daily ET is estimated using a modified Penman equation corrected with experimentally derived crop coefficients. The output from the ET Toolbox is used to support the river modeling and water accounting system (RiverWare) used by the Upper Rio Grande Water Operations Model (URGWOM). Use of the ET Toolbox to evaluate restoration activities is limited by the 4-km grid size, but the basic information used to develop the model is considered important to understanding depletions in the MRG.

Accurate determinations of riparian depletions in the MRG would require site-specific characterization of soil, topographic, flood, groundwater, and vegetation conditions coupled with a quantitative understanding of the response of vegetation to variations in these physical conditions. Thus, until ET relationships are more accurately defined on a site-specific basis, conservatively biased consumptive use values can be used to estimate restoration-related effects on net depletions.

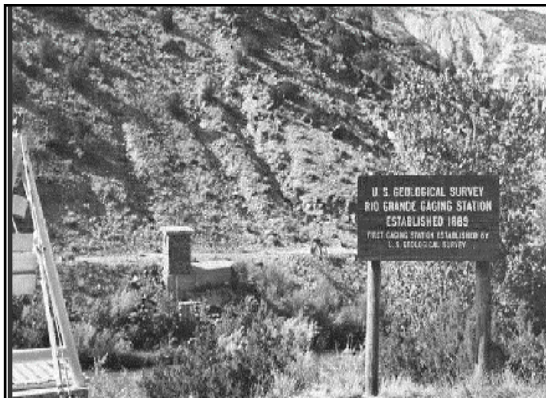
IV. HYDROLOGY

Components of the silvery minnow and flycatcher habitat are influenced by hydrologic conditions. The silvery minnow is an aquatic organism, while flycatcher habitat is typically associated with riparian communities near seasonal or permanent surface water or areas with wet soils. Beyond these simple correlations, the relationship of hydrology to habitat for these species is complex and poorly characterized. For instance, increased flows in the spring are correlated with silvery minnow spawning, but the magnitude and duration of flow needed to optimize the spawn are not known. Floods are considered important for maintaining flycatcher habitat, although the magnitude, frequency, timing, and duration of the events are unspecified.

Because water in the MRG basin is fully appropriated and a large portion of the river flow must be delivered to Texas under the Rio Grande Compact, changes in the amount of water needed to maintain restored areas or to achieve mandated target flows have important societal, economic, and ecological consequences. Ultimately, if additional water is needed for endangered species, an existing water use must be suspended. The intent of this chapter is to provide an overview of the hydrology of the MRG with an emphasis on contemporary conditions, including a summary of the institutional constraints associated with the water management facilities.

HISTORICAL HYDROGRAPH

Stream gaging began in New Mexico in 1888 with the establishment of a gaging training camp by the U.S. Geological Survey (USGS) on the Rio Grande near Embudo. A gaging station was built near the camp and the collection of continuous streamflow records commenced on January 1, 1889 (Borland, 1970). Our understanding of the hydrology of the MRG prior to that time is based on anecdotal accounts and inferences from the archeological record and historical documents. Review of the historical hydrology is meant to provide insights into the conditions in which the silvery minnow and the flycatcher persisted, rather than to define the goals for restoration based on pre-European conditions. In this light, interpretations of the historical record must consider that humans have modified components of the MRG hydrology for at least the last 400 years (Scurlock, 1998). Secondarily, the historical accounts must be considered in context. For instance, General Diego de Vargas in his 1692 trip to the Pecos area described New Mexico's climate "as so very cold with abundant snow and rain and such heavy frost and freezes" (Scurlock, 1998).



U.S. Geological Survey

First USGS gaging station at Embudo, NM

The historical record suggests that the native flows were similar to those seen today. Historical flows in the Rio Grande were generally perennial, except during periods of drought (Scurlock, 1998). Peak flows most often occurred in late spring in response to snowmelt runoff, while episodic floods occurred in association with late summer monsoons. For the 448-year period from 1542 to 1989, Scurlock (1998) estimated that droughts occurred 52 times for a cumulative 238 years. Tree-ring and historical evidence suggests that severe and prolonged droughts occur two to three times each century. Instances of channel drying in the MRG are contained in historical reports, with the first notation in 1752 (Scurlock, 1998). The frequency of reports of channel drying increased in the late 1800s as agricultural irrigation in the upper and middle basins became more prevalent.

References to floods are common in the historical record. Scurlock (1998) estimated that between 1849 and 1942 about 50 moderate to large floods (greater than 10,000 cfs) occurred in the MRG. Several floods were estimated to represent flows near 100,000 cfs. Wozniak (1998) reported that the flood of 1874 destroyed almost every building between Alameda and Barelas. The communities of Tome, Valencia, and Belen were under water during the spring flood of 1884. Tome was later washed away in a 1905 flood (Wozniak, 1998). Property damage and loss of agricultural capacity associated with floods prompted the establishment of flood control measures in the early 1900s.

Changes in upland watershed conditions associated with livestock grazing and timber harvesting likely accentuated runoff associated with extreme weather events (Scurlock, 1995). Impacts of domestic livestock on range conditions were noted as early as the 1700s, with animal numbers increasing into the 1800s and early 1900s. Timber harvesting was accelerated in the late 1800s to support the expansion of railroads. The quantitative impacts of these activities on the MRG hydrograph are unknown, although they are generally considered to have been important.

Agricultural development in the upper Rio Grande basin in Colorado in the late 1800s limited flows to the middle and lower Rio Grande. Agricultural development accelerated in the 1880s and most of the irrigation and drainage infrastructure in the San Luis valley was developed between 1880 and 1890. Consequently, flows from Colorado to New Mexico were reduced by 40 to 60 percent (National Resources Committee [NRC], 1938).

Floods, aggraded channel conditions, poorly drained soils, salinization, and water shortages associated with drought and the upper basin irrigation demands limited agricultural development in the MRG during the late 1800s and early 1900s (NRC, 1938; Wozniak, 1997). From 1880 to 1925, the amount of cultivated land was estimated to range from about 32,000 to 50,000 acres (Wozniak, 1997).

Drainage and flood control projects initiated in the 1930s allowed increased agricultural development and currently about 60,000 acres are cultivated in the MRG. Thus, any comparison to conditions that existed in the early 1900s must be tempered with the understanding that the hydrologic system was substantially modified by that time.

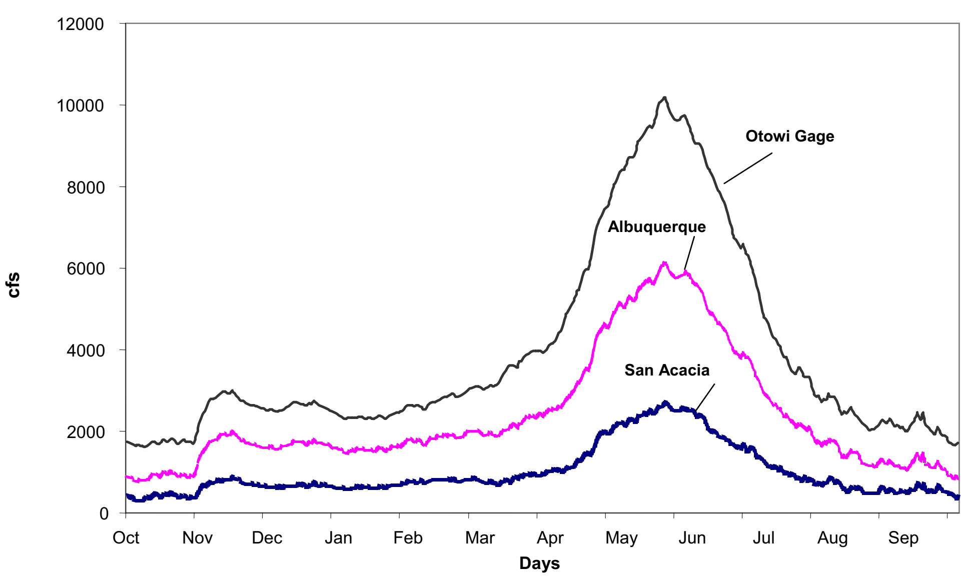
CONTEMPORARY HYDROLOGY

The MRG basin is centered in a semi-arid region where potential evaporation far exceeds precipitation. On average, about 1.1 million acre feet (AF) of water passes the Otowi gage each year. Water is supplied to the Rio Grande about equally from the Upper Basin in Colorado, and the Sangre de Cristo Mountains and Chama watersheds in New Mexico. Consistent with the climate of this region, native flows are subject to significant variability. For example, over the last century, annual mean streamflow at the Otowi gage ranged from about 495 to 3,580 cfs. Details regarding inflows and outflows in the MRG are fully characterized in the SSP&A (2000) water supply study.

The Rio Grande is a losing river through most reaches (Figure IV-1). Water in the river is lost to surface evaporation, ET from riparian vegetation and agricultural crops, and groundwater recharge to riverside drains and the deeper aquifer. Tributary inflows, irrigation return flows and treated municipal wastewater locally augment flow in the river.

Comparison of pre-Heron Reservoir (pre-1971) and post Cochiti Reservoir (1974-1997) flow-duration curves indicates that median daily (i.e., 50 percent exceedance) flows between Otowi and Albuquerque have increased by approximately 200 to 300 cfs (MEI, 2002). The increases in the median daily flow are notably higher in the post-Cochiti period for the Bernardo, San Acacia, and San Marcial gages (Mussetter Engineering, Inc. [MEI], 2002). Thus, the flow in the river was more consistent during the last quarter

Figure IV-1. Average mean daily flow for the period 1971 to 1999.



of the 20th century. The increased flow results from a number of factors, including the importation of SJCP water, changes in the operation of the Rio Grande Conveyance Channel and Low Flow Conveyance Channel, discharges from the City of Albuquerque wastewater treatment plant (about 69,000 AFY), and operation of the flood control dams (MEI, 2002). The relatively wet climate of the 1980s and 1990s also contributed to the observed increase in flow during the post-Cochiti period.

The river rarely dries between Cochiti Dam and Isleta. However, on average, the river is dry about 10 percent of the time at the Bernardo, San Acacia, and San Marcial gages based on USGS streamflow data (MEI, 2002). Prior to the 1970s, the lower reaches of the MRG were dry about 50 percent of the time.

The maximum daily mean flows typically occur in the spring in association with snowmelt runoff from the Upper Basin in Colorado, Sangre de Cristo Mountains, and the Rio Chama watershed (Figure IV-1). Peak flow events typically occur during April and May, although in any given year the peak event may occur in June, July, and August or more rarely in September and October. Annual peak flow events tend to occur more frequently in the late summer (July and August) in the lower reaches and in the spring (April and May) in the upper reaches. Sustained high-volume flows are more likely to occur in the spring rather than in the summer months. The last major floods on the Rio Grande occurred in 1941 and 1942, with flows of approximately 25,000 cfs recorded at the Bernalillo and Albuquerque gages. The largest flow on record in the MRG was 47,000 cfs at the San Marcial gage in September 1929.

Flood control operations at Abiquiu, Cochiti, Galesteo, and Jemez Reservoirs reduce peak flows below Cochiti Dam in some years. Cochiti Dam releases are restricted to the maximum nondamaging downstream channel capacity, currently measured as 7,000 cfs at the Albuquerque gage. Flood control operations at Cochiti Dam are coordinated to account for flow emanating from Galisteo Creek and Jemez River. Peak streamflow at the Albuquerque gage exceeded 7,000 cfs in 13 of the 29 years between 1942 and 1971, while peak flow exceeded 7,000 cfs in 53 of 97 years at the Otowi gage. Thus, based on this simple comparison, current flood control operations result in attenuation of large peaks, but have had little effect on the peak hydrograph in about half the years.

The Rio Puerco and Rio Salado are major tributaries that contribute to late summer peak flows in the lower reaches of the MRG. These drainages are uncontrolled and large scale flooding can be expected in the lower reaches. A maximum peak flow of 18,800 cfs was measured on the Rio Puerco and 36,200 cfs on the Rio Salado.

INSTITUTIONAL CONTROLS

Besides being affected by the limitations imposed by the climate of this region, water operations in the MRG are also partially controlled by complex institutional and legal constraints associated with authorizations of upstream facilities and diversions from the river. The principal constraint on water use in the MRG is defined by the Rio Grande Compact, which was negotiated and signed by the states of Colorado, New Mexico, and Texas, enacted as Public Act No. 96 by the 76th Congress, and subsequently ratified by each state's legislature and approved by President Roosevelt in 1939 (see Chapter III, Depletions).

Water storage, flood and sediment control, and irrigation projects were developed to address the hydrologic extremes and water supply needs in the MRG. In 1935, the MRGCD completed construction of El Vado Reservoir on the Rio Chama for conservation storage of about 198,000 AF, since reduced by sedimentation to about 180,000 AF. In addition, the MRGCD constructed diversion dams at Cochiti, Angostura, Isleta, and San Acacia and more than 180 miles of riverside drains and 160 miles of interior drains associated with about 128,000 acres of irrigable lands. Cochiti Dam replaced the Cochiti Diversion in 1975. The maximum capacities of the diversion structures are 270 cfs at the Cochiti heading, 650 cfs at Angostura, 1,070 cfs at Isleta, and 283 cfs at San Acacia. Maximum diversions at each diversion point can theoretically occur throughout the irrigation season (March 1 to October 31), but the facilities generally operate below their design capacities.

Congress authorized the Middle Rio Grande Project with the Flood Control Acts of 1948 and 1950, with major goals being the reduction of natural depletions in the MRG, improvement of water delivery to Elephant Butte Reservoir, and flood control. A portion of the project consisted of the construction of the Rio Grande Floodway between Velarde and Caballo Reservoir, which included bank stabilization (jetty jack fields), clearing (removal of islands, sandbars, and vegetation), and channelization of parts of the river.

The COE completed construction of Jemez Canyon Reservoir on the Jemez River in 1954; Abiquiu Reservoir on the Rio Chama in 1963; Galisteo

Reservoir on Galisteo Creek in 1970; and Cochiti Reservoir on the Rio Grande in 1975. None of these flood control reservoirs were authorized for conservation storage. The Low Flow Conveyance Channel was completed by the BOR in 1959.

In 1971, the BOR completed the SJCP with the construction of Heron Reservoir on Willow Creek, a tributary of the Rio Chama above El Vado Reservoir. The SJCP has a firm yield of 96,200 AF of water diverted from three tributaries of the San Juan River in southwest Colorado (Navajo, Little Navajo and Blanco rivers). About 54,600 AFY of SJCP water has been delivered to the MRG at the Otowi gage on the Rio Grande since the inception of the project.

Heron Reservoir has a maximum capacity of 401,320 AF. It is authorized to store only SJCP water and all native water is bypassed monthly (about 100 AF per month). Release of stored SJCP water occurs only at the request of contract holders or the New Mexico Office of the State Engineer to offset depletions of native Rio Grande water caused by pumping downstream. Carryover storage of SJCP water is not allowed in Heron Reservoir and all allocated water must be released each year by December 31.

El Vado Reservoir is operated to maximize the storage of native water during periods of flow surplus and can store SJCP waters. Storage rights for the reservoir were assigned to the BOR by the MRGCD in 1963. The reservoir is owned by the MRGCD, except for the outlet works and emergency spillway, which are owned by the BOR. It is currently operated by the BOR under agreement with the MRGCD. The MRGCD specifies releases from this reservoir as needed to augment expected native flows of the Rio Grande in the MRG. Typically, the MRGCD utilizes the native flow of the Rio Grande during spring run-off, and concurrently, attempts to fill El Vado Reservoir on the Rio Chama. When the native flow of the Rio Grande is insufficient for the MRGCD's diversion needs, releases are made from El Vado Reservoir to augment flows. A limited amount of annual storage space (on average about 15,000 AF) is also used for annual reservation of storage to ensure the prior and paramount rights of the six Pueblos in the MRG.

Abiquiu Reservoir, on the Rio Chama downstream from El Vado Reservoir, is authorized to operate for flood control, sediment retention, and storage. Its maximum storage capacity is 1,212,000 AF, with authorizations of 77,000 AF for sediment control and 502,000 AF for flood control, and storage of up to 200,000 AF of SJCP water. When storage of SJCP water is not required, up to 200,000 AF of native Rio Grande water may be stored subject to permitting by the New Mexico Office of the State Engineer and approval by the Rio Grande Compact Commission. Under current operations, normal releases from El Vado are passed through Abiquiu Reservoir with little or no regulation. Because of channel capacity constraints associated with public safety, reservoir discharges are limited to 1,800 cfs directly below the dam, 3,000 cfs at the Chamita gage, and 10,000 cfs at the Otowi gage.

Cochiti Reservoir provides flood protection from flows on the Rio Grande and Santa Fe River. Its initial authorization included only 105,000 AF for sediment control and 500,000 AF for flood control; storage of native water for a permanent pool was specifically prohibited, unless it came from outside of the Rio Grande Basin. Subsequently, Congress authorized a 1,200-acre recreational pool, using about 50,000 AF of SJCP water. An annual allocation of 5,000 AF of SJCP water, originally a portion of the City of Albuquerque's annual allocation, was reserved to replace water evaporated from this pool. No part of this project is allocated to irrigation or other uses. Floodwaters are stored only for the duration needed and are released as downstream channel conditions permit. Releases from Cochiti Dam are coordinated with the operations at the Galisteo and Jemez Canyon Dams to restrict flows at the Albuquerque gage to 7,000 cfs.

Galisteo Reservoir on Galisteo Creek, which has its confluence with the Rio Grande about 8 miles downstream of Cochiti Dam, is authorized only for flood (79,600 AF) and sediment control (10,200 AF). The dam passes all floods up to 5,000 cfs. Normally, this reservoir is dry.

Jemez Canyon Reservoir is on the Jemez River, which enters the Rio Grande about 24 miles downstream from Cochiti Dam. Its authorization includes 40,100 AF for sediment control and 73,000 AF for flood control. Non-flood native flows pass the dam with little or no regulation, except for the constraint of no more than 7,000 cfs at the Albuquerque gage, as noted above for Cochiti Reservoir.

During the first half of the 1900s, accumulated channel sediment significantly impaired flow in the Rio Grande and adversely affected the delivery of water from New Mexico to Texas, as required by the Rio Grande Compact. To address these issues, the COE and the BOR implemented a program of drainage improvements and channel stabilization, including construction of the Low Flow Conveyance Channel to convey water from San Acacia diversion dam to the narrows of Elephant Butte Reservoir. The channel improved drainage, supplemented irrigation water supply, and provided a dependable year-round water supply to the Bosque del Apache National Wildlife Refuge. Diversion of river flows to the lower reach of the Low Flow Conveyance Channel began in 1953 and diversions at San Acacia began in 1960. Diversions into the channel were suspended in March 1985 due to the obstruction of the lower portions by sediment; with minor exceptions, the channel has carried only drainage and irrigation return flows since then.

V. GEOMORPHOLOGY

Fluvial geomorphology is the study of the dynamic interactions of water discharge, sediment load, regional and local geologic controls, and human interventions that affect the morphology of a river (Schumm, 1977). The cross sectional geometry (shape) and planform (pattern) of the Rio Grande's channel and its interaction with the adjacent floodplain are important determinants of habitat quality for the silvery minnow and flycatcher. The shape and gradient of the channel (water surface slope) affects the water velocity, degree of turbulence, and sediment transporting capacity. The topography of the floodplain and its height above the channel affects the ability of the river to connect to the floodplain at a particular discharge point. Geomorphic processes work at different rates, with catastrophic events (e.g., floods) causing large changes that may take significant periods of time to recover from under the influence of more routine flow conditions. Thus, understanding past and present geomorphological relationships and current trends is critical to the design and evaluation of habitat restoration strategies.

Rivers are dynamic systems that adjust their nature in response to changes in the flow and sediment regimes. Like most rivers in alluvial valleys, the location, pattern, and cross-sectional profile of the Rio Grande changes episodically in response to natural variations in flow and sediment supply. Changes in the hydrology and sediment supply following construction and operation of the flood and sediment control facilities in the 1970s have been used to explain the modern channel morphology, including pattern, channel narrowing, channel incision, and changes in bed material composition (Crawford et al., 1993; Graf, 1994; Lagasse, 1994; Baird, 1998 and 2001). The influence of water management operations on the geomorphology of the Rio Grande is undeniable; however, interpretations of cause and effect must also consider the degree of disequilibrium in the system prior to construction of the dams, rates of various processes under natural and anthropogenic conditions, and the episodic nature of sediment dynamics. Interpretation of the Rio Grande geomorphology is complicated by the inherent complexity of the system and general paucity of data from both a temporal and spatial perspective.

HISTORICAL GEOMORPHOLOGY

The earliest detailed information on Rio Grande channel patterns comes from maps associated with a 1917-1918 survey conducted by the U.S. Reclamation Service. As indicated earlier, the hydrology and sediment dynamics of the Rio Grande have been modified by humans since before the 1800s (Chapter IV, Hydrology). By the 1890s, irrigation diversions in the San Luis Basin in Colorado reduced natural flows in the river by 40 to 60 percent (NRC, 1938). Sediment loads to the river were elevated in the late 1800s by arroyo incision and changes in land use in the basin (Happ, 1948). Major increases in sediment load occurred downstream of the Rio Puerco confluence as a result of incision of the Rio Puerco channel associated with watershed degradation (Rittenhouse, 1944; Happ, 1948; Elliott, 1979; Scurlock, 1998).

It is unlikely that the 1917-1918 survey reflects pre-European conditions given the hydrologic modifications of the late 1800s. Nonetheless, MEI (2002) interpreted the 1917-1918 survey to indicate that the river was anastomosing with vegetated islands between Cochiti and Angostura. A braided channel of varying width characterized the river from Angostura to Canada Ancha. The channel narrowed and was confined where the river crosses the Belen-Socorro Uplift above the Rio Puerco confluence. A wide, braided channel with low sinuosity was evident from the Rio Puerco down to San Antonio. From San Antonio to San Marcial, the sinuosity of the channel increased. The average channel width generally increased downstream, with the widest areas associated with sediment contributions from the Rio Puerco and Rio Salado (MEI, 2002). Figure V-1 illustrates end member stream patterns.

CURRENT GEOMORPHOLOGY

As described in Chapter IV (Hydrology), the hydrology of the MRG was altered by irrigation diversions and returns, operation of water supply and flood control reservoirs, flow importation, municipal discharges, and channel and bank modifications. These changes have important implications for the modern geomorphology of the MRG.

GENERAL RELATIONSHIPS

Geomorphic conditions along the Rio Grande from Cochiti Dam to Elephant Butte Reservoir are fully described by MEI (2002). They concluded that realignment and channelization projects resulted in the conversion of the Rio Grande from a multi-channeled, multi-thalweg river through much of its length into a single channel. In general, the river is developing a low-sinuosity meandering channel within the levees associated with stabilization of bars and reduction in the magnitude of peak flows. About 60 percent of the river has a braided channel pattern under low flow conditions between Cochiti Dam and Elephant Butte Reservoir. From Cochiti to near Isleta, many of the bars have become attached to the banks and stabilized by vegetation. Jetty-jack fields and other forms of bank protection currently prevent lateral migration of the river and have eliminated a significant source of sediment, which may be contributing to the channel incision (degradation) observed in the MRG. MEI indicated that localized bank erosion was insufficient to cause major changes in channel patterns. Furthermore, establishment of native and non-native vegetation has effectively stabilized much of the river, especially downstream of San Antonio, where the river has not incised below the rooting depth of the plants (MEI, 2002).

CHANNEL WIDTH

Along the entire MRG, the mean channel width decreased by 24 to 52 percent between 1917-1918 and 1972 (MEI, 2002). Channel narrowing started before the closure of Cochiti Dam (Baird, 2001). MEI (2002) concluded that narrowing of the channel was primarily a result of channelization designed to increase the efficiency of flow conveyance. Evidence of widespread channel narrowing in the MRG between 1972 and 1992 is lacking, except for the reach from San Acacia to Escondida (MEI, 2002). Thus, MEI (2002) concluded that the post-Cochiti hydrologic and sediment regime did not cause channel narrowing in the upper reaches. They related the channel narrowing in the San Acacia to Escondida reach to the combined effects of channel incision (associated with channelization) and establishment of vegetation in the former river channel (associated with flow reductions during the operation of the Low Flow Conveyance Channel). Studies performed by the BOR generally support the conclusion that channel width has stabilized since 1972, although the studies indicated that the reach from Cochiti Dam to the Highway 550 Bridge at Bernalillo is narrowing (Massong et al., 2002).

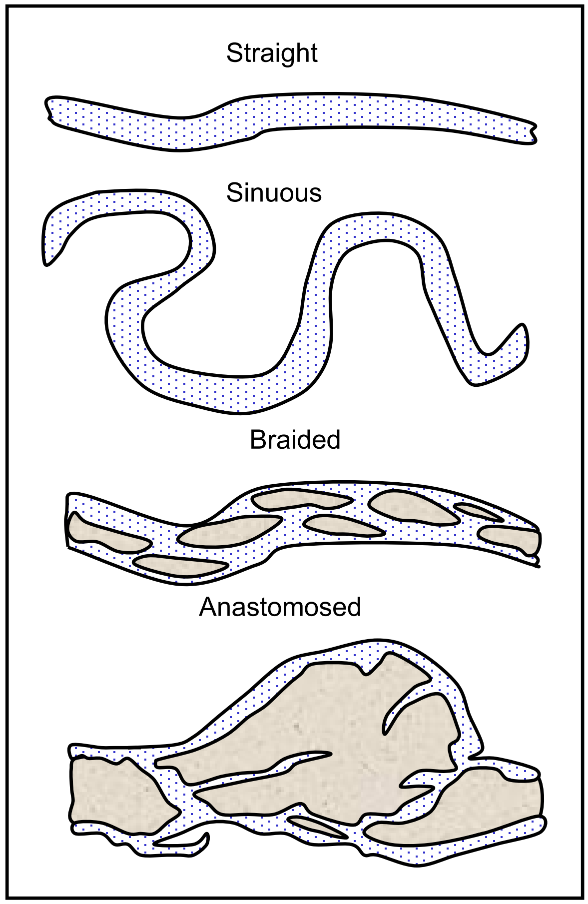


Figure V-1. End member channel patterns.

DEGRADATION/AGGRADATION

Channel degradation, or downcutting, represents the manifestation of a disequilibrium condition that occurs when stream power exceeds resisting power (Bull, 1990). Degradation/aggradation may occur in response to changes in flow velocities, sediment regime (supply and character), and stream gradient (uplift or grade controls). Modern stream terraces, cross-sectional profiles, and field observations indicate that degradation of the Rio Grande channel is widespread from Cochiti Dam to San Marcial, although local areas of aggradation may occur in association with tributary sediment dynamics (Massong et al., 2002; MEI, 2002). In contrast, aggradation is the dominant mode below San Marcial.

The causes for degradation vary locally but can generally be attributed to (1) reduced sediment supply associated with operation of Cochiti Reservoir as well as partial watershed recovery; (2) above normal precipitation in the late 1900s; (3) flow augmentation associated with the SJCP and municipal discharges; (4) suspension of the Low Flow Conveyance Channel operation; (5) uplift associated with the Socorro magma body; and (6) channel realignment, narrowing, and maintenance (Massong et al., 2002; MEI, 2002). Aggradation below San Marcial is likely related to residual sediment from the large floods in the early 1900s and decreased transport capacity associated with the base-level control imposed by the Elephant Butte Reservoir.

Channel degradation reduces the ability of the river to access its floodplain under a given flow regime. MEI (2002) concluded that upstream of Isleta, only minor overbank flooding occurs at a discharge of 5,700 cfs, which has a recurrence interval of about 2 years. Between Isleta and Belen, overbank flooding can be generated at flows on the order of 5,700 cfs. Between Bernardo and San Acacia, the channel capacity is higher than 5,700 cfs and therefore, the frequency of overbank flows is lower. Between San Acacia and San Antonio, flows up to about 5,700 cfs produce some overbank flooding, whereas below San Antonio, extensive overbank flooding is caused by flows in the same range (MEI, 2002).

Natural and artificial grade controls exist on the Rio Grande in association with near surface exposure of more resistant rock, coarse sediment from arroyos, and irrigation diversion structures. These features locally control the potential for degradation and aggradation. In other areas, the rate or potential for degradation is affected by the occurrence of coarse textured bed materials.

BED MATERIAL GRADATIONS

Flood and sediment control reservoirs have had a major effect on sediment and river dynamics downstream of Cochiti Dam (Baird, 1998 and 2001). Suspended-sediment and bed-material loads have decreased relative to the pre-Cochiti Dam period; however, the effects of the dam diminish downstream because of tributary contributions and in-channel sediment sources (MEI, 2002). Downstream from the Rio Puerco confluence, tributary and in-channel sediment sources reduce the potential effects of sediment reductions related to dam operations. In the post-Cochiti period, average annual suspended-sediment concentrations decreased about 99 percent at the Cochiti gage, but only 70 percent at the San Marcial gage. Notably, the average annual suspended-sediment concentrations decreased nearly 55 percent at the Otowi gage during this same period (MEI, 2002).

Basin-wide watershed factors likely explain the reduction of sediment loads at the Otowi gage. Elliot et al. (1999) attributed the decline in sediment load to improved land management practices, reforestation, fire suppression, and the storage of sediment in arroyos that were incised in the 1800s and subsequently widened. Furthermore, it is likely that the relatively wet conditions that prevailed in the 1980s and 1990s has affected sediment production and routing within the MRG basin. A return to drier conditions may result in increased sediment production. The nature of the bed materials affects the response of the channel under various flow regimes in that sand dominated beds are more easily deformed than gravel or cobble dominated beds. In addition, beyond the effects on channel form, bed characteristics may have important direct implications for minnow habitat (Chapter I, Silvery Minnow).

The description of bed characteristics and interpretation of trends is complicated by the relative paucity of historical and current data. Nonetheless, there is fairly broad agreement that the reach immediately below Cochiti Dam has coarsened in response to sediment retention associated with the operation of the dam and that the bed is currently dominated by cobbles and gravels. The channel bed tends to fine downstream, ranging from a sand dominated condition in the reaches below Bernalillo to a clay and silt substrate near Elephant Butte (Massong et al., 2002; MEI, 2002). Zones with higher proportions of gravels occur locally, and especially in association with higher gradient tributaries and below diversion structures. As expected, given the complexity of the Rio Grande geomorphology and the scarcity of data, the interpretation of the causes and trends related to this is controversial (Baird, 1998 and 2001; MEI, 2002).

VI. EXISTING HABITAT CONDITIONS

The MRG contains the last remaining wild populations of the silvery minnow, while its bosque represents important habitat for the flycatcher. Useful working relationships regarding habitat for these species exist, even though the specific requirements are incompletely understood and remain topics of research. Overall, the habitat requirements of the flycatcher are better defined than those of the silvery minnow. A detailed and systematic characterization of habitat resources in the MRG is lacking. The intent of this chapter is to examine current knowledge concerning existing habitat conditions for the silvery minnow and flycatcher in order to facilitate long-term habitat restoration planning.

RIO GRANDE SILVERY MINNOW

The FWS designated the MRG from Cochiti Dam to Elephant Butte Reservoir as proposed critical habitat for the silvery minnow (FWS, 2003b). Figure VI-1 shows the relationship of the FWS designated reaches to other reach designations that have been applied to the MRG. The FWS identified four primary critical elements of habitat for the silvery minnow, including (1) a hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats, including backwaters, shallow side channels, pools, eddies, and runs of varying depths and velocities; (2) the presence of low-velocity habitat within unimpounded stretches of flowing water of sufficient length to provide a variety of habitats with a wide range of depths and velocities; (3) substrates of predominantly sand or silt; and (4) water of sufficient quality to maintain natural, daily and seasonally variable water temperatures and chemical conditions (FWS, 2003b).

The current distribution of the silvery minnow is described in the proposed critical habitat designation (FWS, 2003b). Historically, the silvery minnow occurred upstream of Cochiti Reservoir (Velarde Reach and Chama River). Silvery minnows were collected immediately downstream of Cochiti Dam in 1988, but were not detected during the mid1990s. Nonetheless, the FWS considers the silvery minnow to occur within the Cochiti reach, albeit at very low densities. The Isleta and Angostura reaches contain suitable habitat, and the silvery minnow occurs at low densities. In the San Acacia reach, the silvery minnow is more prevalent than anywhere else in the MRG, but the population densities are still considered low.

The FWS (2003b) described the general environmental conditions in the five reaches of the MRG that contain silvery minnows. However, the most complete reach-specific information is in the Programmatic Biological Assessment (BA) (US BOR/COE 2003) and corresponding Biological Opinion (BO) (FWS, 2003a). Table VI-1 summarizes the dominant physical and biological conditions in the nine reaches defined in the BA. Recognizing that considerable variability in environmental conditions is likely to exist locally within the reaches, habitat conditions are generally less favorable for the silvery minnow in the upper reaches of the MRG than in the lower reaches.

The primary deficiencies in the upper reaches (i.e., Cochiti and Middle) are less than optimum velocity conditions, coarse-grained substrates (Cochiti reach), and a general lack of channel-floodplain connection. Habitat quality is generally better in the lower reaches, but is negatively influenced by inconsistent water supply and a trend toward channel incision. Channel drying in the lower reaches has led to the need for silvery minnow rescue operations; the fish are released near Albuquerque where the flows are more reliable (FWS, 2003a and 2003b).

SOUTHWESTERN WILLOW FLYCATCHER

The draft recovery plan for the flycatcher indicates that the primary constituent elements for habitat include dense thickets of riparian shrubs and trees (native and exotic species) within 100 meters of rivers, streams, open water, cienegas, marshy seeps, or saturated soils that are wet during the May to September breeding season (FWS, 2002). Flycatcher habitat also includes areas where the vegetation or water components are not currently present but may be recovered through rehabilitation (FWS, 2002).

Migratory birds, including the flycatcher, use the MRG riparian corridor as stopover habitat. During

Figure VI-1. Comparison of reach designations between Cochiti Dam and Elephant Butte Reservoir

River Mile	MRGCD Divisions	FWS Critical Habitat	BOR/COE (2003) FWS (2003a)*	MEI (2002)	2002 FWS Habitat Studies Division	2002 FWS Habitat Studies Reach	2002 FWS Habitat Studies Segment
RM 232.6	Cochiti	Cochiti	Cochiti	Cochiti	Pueblo	Pena Blanca	Cochiti Dam
RM 224							Rio Galisteo
RM 220							Borrego Canyon
RM 216.1				San Felipe			
RM 209.7	Albuquerque	Angostura		Angostura		Bernalillo	Rio Jemez
RM 205.2			Middle				
RM 202.5							Arroyo Venada
RM 200					Albuquerque-Belen	Albuquerque Valley	Lomatas Negras
RM 194.2							North AMAFCA
RM 186.8							San Antonio Arroyo
RM 177							South AMAFCA
RM 169.3	Belen	Isleta	Belen	Isleta		Isleta	Isleta Narrows
RM 152.5							Peralta Wastewater
RM 149.5				Belen			
RM 139.3							Abo Arroyo
RM 131							U.S. Highway 60
RM 127					Socorro		Rio Puerco
RM 126.5			Rio Puerco				
RM 121.8						Sevilleta	Bernardo Arroyo
RM 120.6				Canada Ancha			
RM 119							Rio Salado
RM 116.2	Socorro	San Acacia	Socorro	San Acacia		Socorro Valley	San Acacia Dam
RM 105.3							Escondida
RM 104.8				Escondida			
RM 95.2							Bosque Del Apache
RM 87.1				San Antonio			
RM 78			San Marcial			Black Mesa	Tiffany
RM 64							Elephant Butte Delta
RM 58	(to EBR delta)	(to EBR delta)	(to EBR delta)	(to EBR delta)	(to EBR delta)	(to EBR delta)	(to EBR delta)

* Biological Assessment/Biological Opinion also included the Velarde, Espanola, and White Rock reaches upstream of Cochiti Reservoir.

Table VI-1. Summary of dominant conditions influencing existing habitat in the Middle Rio Grande (Adapted from BOR/COE 2003 unless otherwise noted).

	Reach							
	Velarde	**Espanola**	**Cochiti**	**Middle**	**Belen**	**Rio Puerco**	**Socorro**	**San Marcial**
River Miles	284-271	271-258	232-204	204-177	177-135	135-125	125-78	78-69
Reach Length (mi)	13	13	28	27	42	10	38	18
2-yr Return Peak Discharge (cfs)	4,360	8,050	5,650	4,820	4,820	4,000	9,100	2,400
Bankfull Width (ft)[1]	210	370	391 ± 162	598 ± 109	540 ± 86	610 ± 292	547 ± 447	444 ± 387
Bankfull Depth (ft)	4	4.7	4.5	3.5	3.1	2.8	3.3	4.3
Channel Substrate	gravel, cobble	gravel, sand	gravel	sand, gravel locally in upper reaches	predominantly sand	sand, silt	sand, silt, and clay; increasing gravel	sand with silt and clay
Channel Condition	stable, low entrenchment	degrading, local braiding	degrading, high entrenchment	degrading, entrenched, disconnected bars	degrading, disconnected bars, islands	transitional aggrading to degrading, bars, islands	transitional degrading to aggrading	aggrading
Bank Conditions	fine grained material	gravel with some sand, active erosion	highly erosive sand	stable, well vegetated, jetty jacks	stable, well vegetated, jetty jacks	stable, well vegetated, jetty jacks	stable, well vegetated, jetty jacks	stable, well vegetated
Overbank Flooding Potential	dependable	limited	minimal	limited	regularly below Bernardo	regular flooding occurs	regular flooding occurs	regular flooding occurs
Riparian Zone	narrow, limited exotic invasion	mature native stands with increasing exotics	limited riparian vegetation	mature, even-aged cottonwood; dense saltcedar	mature, even-aged cottonwood; dense saltcedar	dense saltcedar	dense saltcedar	dense saltcedar, cottonwood and willow
Fire Potential	--	--	--	high	high	high	high	high
Silvery minnow Presence	none	none	present	present	present	present	present	present
Flycatcher Presence	present	no data	no data	no data	present	none	present	present
Flycatcher Nesting	present	none	none	no data	present	none	present	present

[1] Bankfull width for Velarde and Espanola from the BA; other reaches are mean and 1 standard deviation from 1997 aerial photographs interpreted by Paul Tashjian (FWS).

the spring and fall migrations, flycatchers use a variety of riparian and non-riparian habitats, with some evidence indicating that they are more commonly found in willow dominated habitats than in cottonwood, mixed exotic, or mowed willow sites (Yong and Finch, 1997; Finch et al., 2000a). Presence/absence surveys indicate that flycatchers use vegetation types classified as "low suitability" (see description of suitability categories below) for breeding habitat (Ahlers and White, 2001).

Recently confirmed breeding territories in the MRG include the areas around Velarde, Isleta Pueblo, Sevilleta National Wildlife Refuge, San Acacia, Bosque del Apache National Wildlife Refuge, and San Marcial. Habitat within these reaches includes dense stands of willows and saltcedar, near the river or other water sources, with or without a cottonwood overstory. Some areas in the MRG contain apparently suitable flycatcher habitat (e.g., the Cochiti and Middle reaches); however, no established territories have been confirmed recently (FWS, 2003a).

The BOR developed a flycatcher habitat suitability model in 1998 that was further refined in 1999 (Ahlers and White, 2001). The habitat mapping was based on Hink and Ohmart (1984) vegetation classes with breeding habitat suitability identified in appropriate vegetation units that are within 100 m of existing watercourses or ponded water, or are in the zone of peak inundation. The five suitability categories are as follows:

- **Highly Suitable Native Riparian** – Stands dominated by willow and cottonwood
- **Suitable Mixed Native/Non-native Riparian** – Stands of native mixed with various compositions of non-native species
- **Marginally Suitable Non-native Riparian** – Stands composed of monotypic saltcedar or stands of saltcedar mixed with Russian olive
- **Potential with Future Riparian Vegetation Growth and Development** – Stands of very young sparse riparian plants on river bars that could develop into stands of adequate structure
- **Low Suitability** – Areas where native and/or non-native vegetation lacks the structure and density to support breeding flycatchers

Currently, the FWS groups the first three categories as equally suitable because of the presence of nesting sites in habitats classified as Suitable or Marginally Suitable (FWS, 2003a). To date, the BOR habitat mapping has only been applied in the Socorro and San Marcial reaches.

Comprehensive mapping of the floodplain vegetation along the MRG was conducted in the late 1980s as part of the National Wetland Inventory (Roelle and Hagenbuck, 1994); however, this work has not been adapted to quantify potential flycatcher habitat. Similarly, Hink and Ohmart mapped the vegetation in portions of the MRG in the late 1980s. Neither of these vegetation maps account for recent changes in vegetation associated with disturbance (e.g., fire) or shifts in land use. Nonetheless, it is possible that they could be adapted for habitat restoration planning in the absence of more detailed work.

General descriptions of the vegetation by reach are provided below based on the information contained in the BA (BOR/COE, 2001). The riparian habitat in the upper MRG (Velarde and Espanola reaches) includes dense willow and cottonwood stands adjacent to or near the river. The bosque in the Cochiti reach contains mainly mature stands of cottonwood and lacks the dense understory needed by flycatchers. However, Russian olive, Siberian elm, and other non-native species are becoming more prevalent in the Cochiti reach.

In the Middle reach, the bosque is similar to the Cochiti reach in that it contains mainly even-aged stands of mature cottonwoods and has significant patches of non-native vegetation. Thus, both the Middle and the Cochiti reaches contain suitable flycatcher habitat. The lack of breeding territories in the Cochiti and Middle reaches is problematic given the apparent occurrence of suitable habitat.

In the Belen and Rio Puerco reaches, habitat known to support breeding pairs consists of dense willow and cottonwood stands associated with floodplain marshes below the Isleta Diversion Dam and areas adjacent to the river within the Sevilleta National Wildlife Refuge containing saltcedar and Russian olive (FWS, 2003a).

The Socorro and San Marcial reaches contain high-value riparian ecosystems. Native riparian trees and shrubs are interspersed with stands of non-native riparian plants, primarily saltcedar and Russian olive. Detailed habitat mapping has been conducted in the Socorro and San Marcial reaches, where about 1,700 acres of highly to marginally suitable habitat have been identified (FWS, 2003a).

VII. ESTIMATED FUTURE HABITAT CONDITIONS

The intent of this chapter is to discuss future conditions in the MRG, with an emphasis on silvery minnow and flycatcher habitat and assuming no interventions. The future is casually defined to represent about the next decade. Precise predictions of the direction and amount of change in complex biological systems are not possible. In addition, an understanding of the species' habitat requirements and controlling environmental factors complicates the prediction of future habitat conditions.

From a broad perspective, the magnitude and rate of change of habitat in the near future is expected to be relatively minor compared to the changes that occurred historically. Nonetheless, the silvery minnow and flycatcher populations are at risk and even minor losses of habitat are important. Locally, the silvery minnow is generally considered to be at greater risk than the flycatcher, because its population is restricted entirely to the MRG.

RIO GRANDE SILVERY MINNOW

The two primary determinants of present and future habitat for the silvery minnow are hydrology and geomorphology. The following summarizes present trends in hydrology and geomorphology with respect to future conditions for silvery minnow habitat.

HYDROLOGY

Projections of silvery minnow habitat related to water supply assume that the current physical and institutional infrastructure for water management will remain constant. In the very near term, the water supply outlook is not encouraging. The basin experienced somewhat wetter than normal conditions during the last two decades of the 20th century, and the episodic droughts that characterize this region have been short and only moderately severe since the 1950s. Thus, the possibility of a prolonged, severe drought is increasingly probable. Reservoir storage is currently at extremely low levels, and even with the possibility of above normal winter precipitation, the Rio Grande Compact limits the amount of water that can be held in storage upstream from Elephant Butte Reservoir. Thus, water supply will continue to be highly dependent on near-term climatic conditions.

Lewis Munk

El Vado Reservoir at 3% storage capacity (11/02)

From a practical view, increasing human populations will increase the demand for water and further constrain the hydrology of the system. Continued development and population growth in Espanola, Santa Fe, Albuquerque, the Pueblos, and other communities in the Rio Grande corridor will stress the system either directly by increased use of surface water or indirectly through the use of tributary groundwater. Shifts in land use from irrigated agricultural to urban and industrial uses or the application of conservation measures may result in changes in consumptive use. Development within the historical, but now protected, floodplain is likely to perpetuate the need for flood control measures.

Ultimately, the water supply for the silvery minnow is dependent on wet-dry cycles and complex institutional constraints. Silvery minnow habitat will continue to be threatened in the lower reaches by water supply issues. Pumping to maintain instream flows and rescue efforts will continue to be necessary to maintain habitat in the lower reaches. As human populations increase, more frequent periods of channel desiccation are expected in drought years and potentially in more normal years, especially between Albuquerque and Elephant Butte Reservoir. Water supply issues are accentuated by the relatively high proportion of the silvery minnow population in the lower reaches of the MRG.

GEOMORPHOLOGY

The morphology of the channel and character of the bed are important considerations with regard to silvery minnow habitat. The habitat preference of the silvery minnow is currently characterized as shallow channels with silty to sandy beds during most of the year. However, during the late fall and winter, silvery minnows concentrate in deeper pools. Channel features that promote turbulent flow and low-velocity environments during peak flows and restrict downstream transport of eggs and larvae are important during the spring spawning period. Connection of the channel to the floodplain through overbank flooding is considered important for nutrient cycling. Channel pattern is not intrinsically important except as it affects velocity and substrate characteristics. The geomorphology of the Rio Grande was described in Chapter V. The balance of this section is primarily based on interpretation of a summary analysis provided by Massong et al. (2002).

The Velarde and Española reaches are expected to trend toward slightly increasing width, sinuosity, and braiding and decreasing depth. Minor overbank flows are expected, except for some upstream portions of the Velarde reach (Massong et al., 2002). Because the silvery minnow does not occupy these reaches, geomorphic changes are not expected to influence the silvery minnow habitat.

The Cochiti reach is expected to change from a sand-silt dominated bed to a gravel-cobble dominated bed because the supply of fine sediments from the principal upstream sources (e.g., Santa Fe, Galisteo, and Jemez rivers) is captured in reservoirs. The channel is expected to narrow and increase in sinuosity (Massong et al., 2002). Habitat quality is expected to decrease in this reach in response to the coarsening of bed sediments.

The Middle reach historically had a wide, braided, aggrading channel with a sand bed that was considered unstable. It has been stabilized in recent decades by channel realignment, installation of jetty jacks, and flow regulation. The most recent BOR data indicate that sinuosity is increasing and the bed is coarsening (i.e., increased gravel), especially in the upper portions of the reach. The coarsening of the bed and increasing meander tendency suggest that the channel is becoming less stable (Massong et al., 2002). The BOR analysis suggests an increase in island development, relatively stable channel widths and average depths, and increased maximum channel depths during the 1990s. Geomorphic trends were not projected by the BOR. However, increasing proportions of gravel in this reach would, presumably, diminish habitat quality for the silvery minnow. In contrast, increasing island development could improve aquatic habitat quality by providing a more diverse flow environment.

The channel in the Belen reach is constrained by realignment efforts and jetty jacks. The projected trend in the Belen reach is for minor degradation concentrated in the lower 12 miles of the reach. Significant changes from the medium to coarse sand bed that currently dominates this reach are not expected. Over the past 3 years, vegetated medial bars (islands) have become more prevalent (Massong et al., 2002). Degradation is likely to reduce the potential for overbank flooding, although this may be offset by the development of islands. Thus, habitat conditions are expected to be static but with the potential for some improvement.

The greatest influence on channel conditions in the Rio Puerco reach is associated with channel realignment and construction of berms and jetty jack fields in the 1950s and 1960s. Historically, much of this reach was characterized as a low-flow, braided channel with a sandy substrate. Currently, the channel is converting to a single channel upstream of the Sevilleta National Wildlife Refuge "bend," while maintaining a braided channel downstream. Average channel width appears to be stabilizing, while average and maximum channel depth and the average size of bed material are reportedly increasing (Massong et al., 2002). The Rio Puerco reach is currently degrading. As with the other reaches, increasing the diversity of shallow and deep-water habitats should benefit the silvery minnow, but reduction of braiding upstream of Sevilleta may adversely affect habitat.

The Socorro reach includes two subreaches divided 21 miles downstream at the Arroyo de las Canas. The upper of these two subreaches continues to be heavily influenced by channel realignment associated with construction of the Low Flow Conveyance Channel in the 1950s and 1960s and additional channel work in 1972. Massong et al. (2002) indicated that the bed is coarsening and the depth of the channel is increasing. In the downstream subreach, the dominant bed material is coarse sand with minor accumulations of gravel. The relatively wide channel is mostly straight, braided, and has an accessible floodplain. The channel in this subreach is narrowing with declining connection to the floodplain (Massong et al., 2002). The general trend of deepening, bed coarsening, and reduced connection to the floodplain may reduce habitat quality for the silvery minnow.

Most of the San Marcial reach is characterized by a narrow, single-thread pilot channel developed between 1949 and 1962. The channel is straight and narrow with vegetated, stationary banks composed of relatively fine-textured materials (clays, silts, and sands). Recent data indicate that this reach is aggrading, particularly in the downstream portions (Massong et al., 2002). Overbank flooding occurs at flows of 2,000 to 3,000 cfs. Continued aggradation in this reach will increase the potential for overbank flooding. Habitat conditions for the silvery minnow are expected to remain constant or improve in the near future.

SOUTHWESTERN WILLOW FLYCATCHER

Suitable habitat for the flycatcher generally consists of dense riparian vegetation interspersed with small openings and associated with slow-moving or still surface water and/or wet soils (Sogge and Marshall, 2000). Flycatchers establish nests in vegetation patches ranging from 1 to 40 acres that are relatively isolated during the breeding season. In the foreseeable future, the primary changes in flycatcher habitat are predicted to be associated with urban development, wildfires, and changes in plant communities.

The area categorized as riparian forest in the MRG has not appreciably changed over about the last century, although the distribution and composition of the stands are different (Crawford et al., 1993). Changes in the distribution of plant communities resulted from the early agricultural developments and drainage projects. Shifts in plant community composition are attributed to the introduction of exotic plants (e.g., saltcedar and Russian olive). The hydrologic changes that coincided with the introduction of these species probably accelerated their expansion in the MRG. In some areas, saltcedar has become established in dense monotypic stands to the exclusion of other plant communities. In other areas, the exotic species are components of mixed stands.

Clearing of riparian vegetation for agriculture results in loss of habitat and creates disturbances to plant and animal communities in adjacent areas (Crawford et al., 1993). Agricultural development may also create foraging sites for the brown-headed cowbird, which could increase parasitism in nearby flycatcher territories (FWS, 2002). Given the current water supply considerations and regional trends towards urbanization, increased agricultural development is not expected in the foreseeable future. However, urban and residential development is expected to increase.

Urban development is not likely to result in direct destruction of habitat, but could indirectly affect flycatcher habitat. Road and bridge construction in riparian areas can result in habitat fragmentation. Fragmentation has been found to reduce carrying capacity and is likely to result in diminished habitat quality (Marshall and Stoleson, 2000).

Increased recreation in riparian zones is likely with urban development. Recreational developments (e.g., picnic areas and trails) can directly destroy habitat and disrupt nesting birds (Finch et al., 2000b). Thus, an undetermined amount of loss and fragmentation of flycatcher habitat is expected in association with residential growth in this region.

Fire is a concern with respect to flycatcher habitat and can result in direct destruction of breeding sites and shifts in plant community structure (Paxton et al., 1996; FWS, 2002). On average, about 850 acres of bosque burn per year, based on a review of fire records for the Rio Grande Valley for the 1985 to 1995 period (Stuever, 1997). The burned areas were mostly small (< 5 acres) but ranged up to more than 1,900 acres. Cottonwood stands are susceptible to fire mortality and replacement by saltcedar, which regenerates quickly and is a vigorous competitor (Stuever, 1997; Marshall and Stoleson, 2000). Busch (1995) speculated that the frequency and intensity of wildfires in riparian areas have increased as fuels have accumulated in association with reduced flooding and the saltcedar expansion. Because humans start most of the fires in the bosque, fire frequencies are expected to continue to increase with increased population in the MRG (Stuever, 1997; Crawford et al., 1993).

The successful establishment of flycatcher breeding territories in saltcedar complicates the interpretation of the long-term effects of fire and shifts in plant community composition on flycatcher habitat. The relative value of native versus non-native plant communities is not completely understood, although native communities are believed to be better habitat (FWS, 2002). The time-transgressive invasion of saltcedar, and other exotic species, is expected to continue as a result of natural competitive pressures, water operations, and fire. This trend is expected to reduce habitat quality for the flycatcher, although the magnitude of loss is not well defined.

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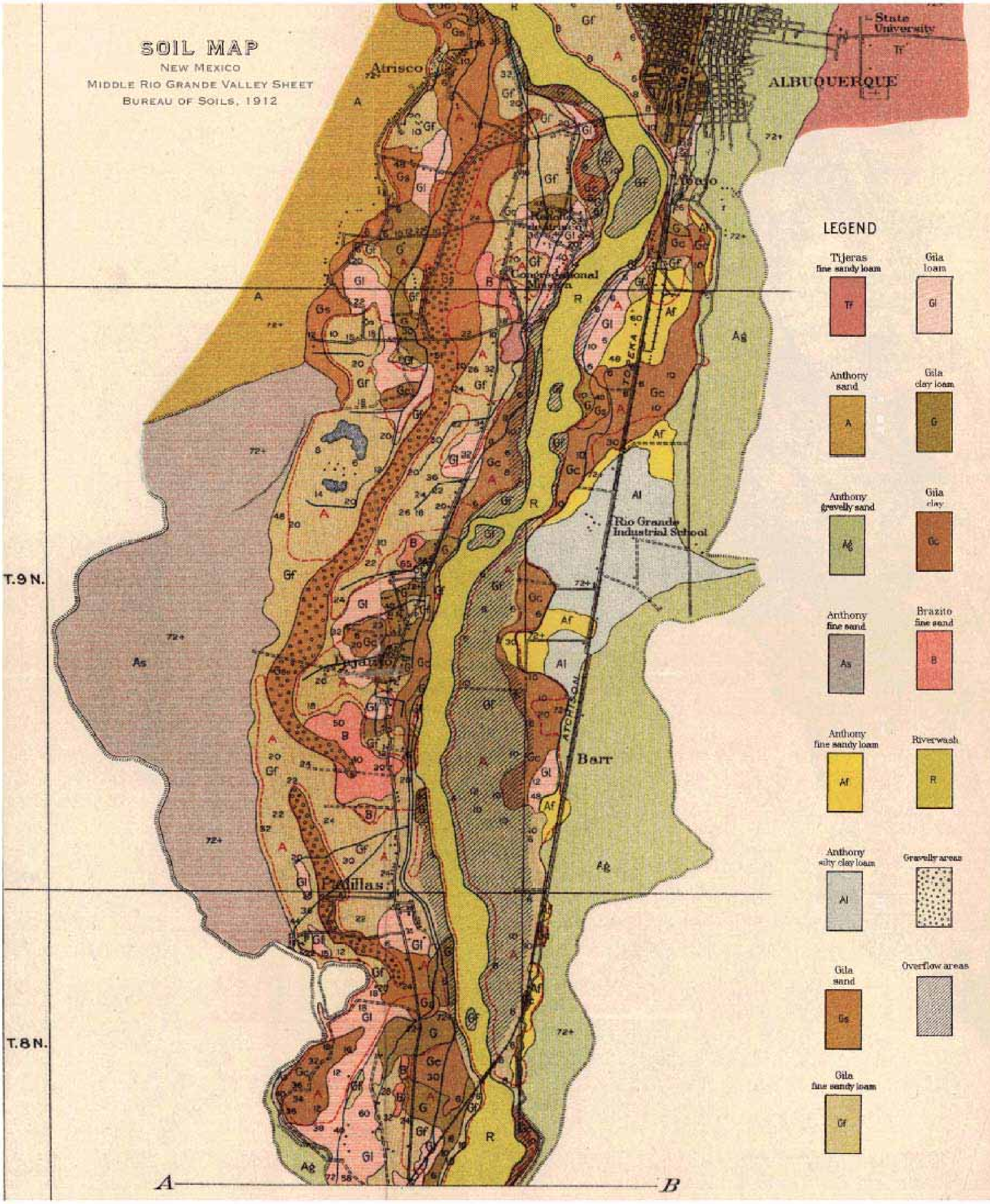
SOIL MAP
NEW MEXICO
MIDDLE RIO GRANDE VALLEY SHEET
BUREAU OF SOILS, 1912
LEGEND
Tijeras fine sandy loam
Gila loam
Anthony sand
Gila clay loam
Anthony gravelly sand
Gila clay
Anthony fine sand
Brazito fine sand
Anthony fine sandy loam
Riverwash
Anthony silty clay loam
Gravelly areas
Gila sand
Overflow areas
Gila fine sandy loam
State University
ALBUQUERQUE
Atrisco
Barelas
Congregational Mission
Rio Grande Industrial School
Pajarito
Barr
Padillas
TOPEKA
ATCHISON
T.9 N.
T.8 N.
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